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Research Article

Can Scientific Literacy Boost Early Childhood Special Education Teachers' Competencies Through STEAM-Based?

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Abstract: To enhance teacher proficiency, this study explores the possible effects of integrating STEAM (science, technology, engineering, arts, and mathematics) principles into the early childhood special education (ECSE) curriculum. The present study centers on science literacy's function in enhancing educators' competencies working with young children. A growing number of people are realizing the significance of STEAM education for the storytelling of the future as the field of education advances. This mixed-methods study assesses ECD instructors' existing scientific literacy level and the efficacy of STEAM-based interventions in enhancing their competencies through quantitative surveys and qualitative interviews. This study aimed to identify key issues and opportunities associated with incorporating STEAM components into ECSE programs and provide insights into the benefits that can accrue to teachers and students. This study describes the relationship between scientific literacy, STEAM education, and ECSE teacher proficiency. The findings will teach educators, policymakers, and curriculum developers about the benefits that STEAM principles can bring to ECSE organizations. Ultimately, this will promote a more inclusive learning environment.

Anahtar Sözcükler:

Bilimsel okuryazarlık,

Okul öncesi eğitim

Özel öğretim

Öğretmen yeterlilikleri

Fen, teknoloji, matematik, sanat ve mühendislik tabanlı eğitim (FeTeMSaM)

Bilimsel Okuryazarlık, FeTeMSaM Tabanlı Yaklaşımla Erken Çocukluk Özel Eğitim Öğretmenlerinin Yetkinliklerini Artırabilir mi?

Bu çalışma, öğretmen yeterliliklerini artırmak amacıyla, bu çalışma fen, teknoloji, mühendislik, sanat ve matematik ilkelerinin erken çocukluk özel eğitim müfredatına entegrasyonunun olası etkilerini incelemektedir. Buna paralel olarak, bu çalışmada bilimsel okuryazarlığın küçük çocuklarla çalışan eğitimcilerin yetkinliklerini geliştirmedeki rolüne odaklanılmıştır. Eğitim alanındaki gelişmelerle birlikte, giderek daha fazla kişi fen, teknoloji, mühendislik, sanat ve matematik eğitiminin geleceğin anlatısındaki önemini fark etmektedir. Bu karma yöntemli araştırma, erken çocukluk dönemi öğretmenlerinin mevcut bilimsel okuryazarlık düzeyini ve fen, teknoloji, mühendislik, sanat ve matematik temelli müdahalelerin öğretmen yetkinliklerini geliştirmedeki etkinliğini nicel anketler ve nitel görüşmeler aracılığıyla değerlendirmektedir. Çalışmanın amacı, erken çocukluk özel eğitim programlarına fen, teknoloji, mühendislik, sanat ve matematik bileşenlerini dahil etmenin beraberinde getirdiği temel sorunları ve fırsatları belirlemek ve bu bileşenlerin öğretmenler ile öğrenciler açısından sağlayabileceği faydalara ilişkin içgörüler sunmaktır. Bu araştırma, bilimsel okuryazarlık, fen, teknoloji, mühendislik, sanat ve matematik eğitimi ile erken çocukluk özel eğitim öğretmenlerinin yetkinlikleri arasındaki ilişkiyi ele almaktadır. Elde edilen bulgular, eğitimciler, politika yapıcılar ve müfredat geliştiriciler için fen, teknoloji, mühendislik, sanat ve matematik ilkelerinin erken çocukluk özel eğitim kurumlarına sağlayabileceği faydalara dair önemli bilgiler sunacaktır. Nihayetinde, bu durum daha kapsayıcı bir öğrenme ortamının teşvik edilmesine katkıda bulunacaktır.

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1. Introduction

A child's early years are a time of distinct development and growth for each child who has intellectual (IQ), emotional (EQ), and spiritual (SQ) abilities (Mishra, 2022). At this stage, the learning process should provide basic concepts that have meaning for children through real-life experiences that allow them to demonstrate their activity and curiosity to the greatest extent possible (Murayama et al., 2019). The early childhood education program is for children aged 0 to 5 (Findlay, 2019). As a result, early childhood must be stimulated appropriately during its development period. Additionally, when instructing international students, teachers should adopt different approaches (Horwitz, 2020). One crucial factor that must be ignored to achieve good results when raising an infant's quality of life is the teacher's professionalism in teaching (Fontana, 1995; Hargreaves & Fullan, 2015; Tanang & Abu, 2014). To face the industrial revolution, educators and students must be brave and ready to take new steps 4.0 (Lase, 2019; Maryanti et al., 2020). In this 21st-century education, creativity, critical thinking, teamwork, problem-solving, communication skills, mass society, and character are all emphasized (Kennedy & Sundberg, 2020; Rahman, 2019). The twenty-first century relies on knowledge and skills where students must think critically, rationally, and logically (Greenstein, 2012; Mardhiyah et al., 2021). Subsequently, it also focuses on character development and independent learning by involving students in problem-solving. 21st-century skills encompass the following: (a) life and career skills, (b) the ability to learn and innovate, and (c) proficiency in navigating media, information, and technology (Gut, 2011; Kennedy & Sundberg, 2020; Trilling & Fade, 2009).

Today's generation must be prepared to possess soft and hard skills derived from their education in daycare centers, traditional schools, and private tutoring (Handayani & Marbun, 2019; Wagner & Venezky, 1999). The skills required in the twenty-first century are divided into four categories: literacy, inventive thinking, effective communication, and increased productivity (Omar et al., 2012). Scientific literacy is one of the most crucial reading abilities to acquire at a young age. In 1993, UNESCO recognized the importance of science literacy in Indonesia (Astuti, 2016; Siagian et al., 2017). The 2006 curriculum (KTSP) started incorporating scientific literacy through inquiry-based learning and scientific methods, and the 2013 curriculum makes this more evident. It is expected that future early childhood teachers will become more professional in teaching scientific literacy to students and preparing excellent students from an early age. As a result, teacher achievement and competitiveness can improve (Mashford-Scott& Church, 2011; Sitorus et al., 2020).

The PISA (Program for International Student Assessment) 2018 results show that the average score across all member countries of the OECD (Organization for Economic Cooperation and Development) is 489 (Bayirli et al., 2023; Thomson et al., 2019). Indonesia has promoted the national literacy movement since 2017 (Noor, 2020; Sulistiyarini, 2021). However, Indonesia only received a score of 386 (OECD, 2019), which is still below the average. According to the 2001 No Child Left Behind law (UU No. 107–110) and its implementation in the early childhood education program, which emphasizes "good start, grow smart," it is crucial to recognize the quality of the early childhood education program and the optimal growth of the child have increased over a few years (Fadillah & Istikomai, 2021). An essential subject in early childhood education is science (Barenthien et al., 2020; Eshach & Fried, 2005). It is well-known that children have a strong desire to understand their environment better and are eager to do so. Children are also gifted at learning to interact with their surroundings (National Research Council, 2002)]. Early childhood is full of wonder (Şentürk & Sari, 2018). They want to know about and investigate their surroundings, so they

try to do things. Early childhood education is, therefore, the best period for educators to introduce science literacy to their children (DeBoer, 2000; Gerde et al., 2018; Kinmonth-Schultz & Simone, 2025; Otto, 2015).

Several related studies on early childhood education have been conducted by researchers worldwide. They found that integrating STEAM-PJBL into science instruction helped students understand how scientific understanding of phenomena relates to real-world situations (Adriyawati et al., 2020; Mercan & Gözüm, 2023; Zayyinah, 2022). It enhanced students' interest and problem-solving abilities, pushing them to pose questions and investigate other information sources. Additionally, research indicates that STEAM-based non-typed media might enhance students' critical thinking abilities, positively influencing scientific literacy (Twiningsih & Elisanti, 2021). Around 3.5% of the students performed well in creative thinking skills, receiving a score of 82.7%. In the high category, utilizing social media to incorporate STEAM project learning within the learning process can help students process abilities in science, creative thought capacity, scientific and digital literacy, and motor skills (Suryaningsih & Nisa, 2021). These discoveries can be used to enhance scientific education. Early childhood education teachers in the Bireuen district still struggle with literacy, particularly science. According to a survey by the Indonesian Government Apparatus Capacity Building Organization (LEPENKAPI) Bireuen, mastery of scientific literacy in early childhood education remains low. Moreover, one barrier to using science learning in early childhood education is the absence of suitable facilities for the science curriculum. Early childhood educators are qualified educators who work with children, providing them with instruction, direction, training, assessment, and evaluation. They also have a strong scientific foundation in child development. One strategy to raise the caliber of teachers is to provide them with training on using scientific literacy in the early years.

Based on our findings, we held a workshop to help early childhood teachers in the Bireuen district improve their STEAM-based scientific literacy. This workshop is a response to the findings of the LEPENKAPI 2021 survey; this demonstrated that the Bireuen district's early childhood education program lacked scientific literacy instruction. This research aims to improve teacher competency in implementing STEAM-based scientific literacy. This study attempts to answer the following research questions:

1. Is there any significant difference in achievement before they are put under treatment and after the treatment of STEAM-based literacy science?
2. How do teachers respond to implementing STEAM-based literacy science?

2. Method

2.1. Research Design

Using the pre-experimental design, a single group underwent a pre-test and post-test. A group of research volunteers is tested on the dependent variable, O, before administering the treatment condition. Once the independent variable, X has been administered, the dependent variable, O, is measured again. The difference in pre-test and post-test scores is used to assess the effectiveness of the treatment condition. Pre-test, treatment, and post-test are all part of a one-group pretest-posttest design together with one group (Newman, 2014). The researcher studies a single group and provides an intervention during the experiment with pre-experimental designs. This design has no control group compared to the experimental group (Creswell & Zhang, 2009). In a one-group pre-test/post-test design, a single group of participants receives a post-test following their pre-test and an experimental treatment condition (Johnson & Christensen, 2008).

2.2. Participants

The study's participants comprised early childhood educators in the Bireuen district. Fifty early childhood education teachers were selected as samples. To collect data for this study, simple random sampling is used as a research procedure (Cohen & Huffman, 2007). There is an equal and independent probability that every member of the studied population will be selected as the sample in a simple random selection. Though most studies on education cannot use it, simple random sampling is generally considered the best approach. In essential random sampling, each member of the defined population has an equal and independent chance of being chosen to be a part of the sample.

Additionally, as each member of the population has an equal probability of being selected, the selection process for individuals can be determined using random sampling (Creswell & Zhang, 2009). The total number of early childhood education centers in Bireuen Regency is 227. The researchers selected 10 early childhood education programs as a sample. 50 Early Childhood Education teachers in Bireuen Regency were involved; they are from Idhata Kindergarten, Cut Meutia Kindergarten, Cut Nyak Dhin Preschool, Pertiwi Kindergarten, Lina Modern Preschool, Jasa Bunda Kindergarten, Sirajul Huda Kindergarten, Peuteunang Hate Kindergarten, Nusa Indah Kindergarten, and Al-Muna Kindergarten.

2.3. Data Collection

This study used two instruments, namely tests and questionnaires. A test is a type of measurement that focuses on eliciting a specific sample of performance (Duff & Bachman, 2004). The test was administered both in pre-test and post-test. The teachers were required to answer 20 multiple-choice questions. The questionnaire is a highly structured tool for gathering data consisting of several items that pose exact queries or provide the respondent with multiple alternatives (Bowling, 2005). The researchers used a closed-ended questionnaire for early childhood education teachers that included 15 questions about STEAM-based scientific literacy. This questionnaire was adapted (Dörnyei, 2014) and administered following the post-test. The respondents in this study were 50 early childhood teachers from the Bireuen District. A pre-test with 20 multiple-choice questions is distributed to each teacher. They were then given a 15-day online literacy science treatment. The material for early childhood teachers is about STEAM (Science, Technology, Art, and Math) scientific literacy. The teachers used simple materials such as bottles, mineral water, nails, tape, and dye to demonstrate how a tornado occurs. Then, they demonstrated volcanic lava using Jess Cool, cooking oil, glitter, water bottles, and dish soap. Following treatment, the teachers were given a post-test of 20 questions to determine whether there was an improvement in early childhood teachers' understanding of STEAM-based scientific literacy. During the initial meeting, a pre-test was given to the teacher to ascertain their beginning understanding of scientific literacy and early childhood STEAM topics. The second through eighth meetings were devoted to the theory of scientific literacy and STEAM.

2.4. Data Analysis

Tutors demonstrated STEAM-based scientific literacy learning in early childhood from the ninth to the fourteenth meeting. At the 15th meeting, the tutor administered a post-test of 20 questions. Lastly, the Statistical Package for Social Sciences (SPSS) version 22 software analyzed the data.

3. Findings

There are 50 valid data points or N and zero missing data points. This implies that the processing of all data is possible. There are two tests: pre-tests and post-tests. The pre-test has a minimum value of 50, the post-test has a value of 70, and the highest is 85. The pre-test mean, or average value, is 61.50, and the post-test mean is 76.20. The before-test's standard deviation is 5.825, but the post-test's is 5.107. Sig. value in the Shapiro-Wilk section; in this instance, 0.507 with df 50 corresponds to science literacy. A determination is made that the data is usually distributed since the sig. The value exceeds the alpha significance level (5% or 0.05). For Teacher Competence with df 50 of 0.571. A determination is made that the data is usually distributed since the sig. The value exceeds the alpha significance level (5% or 0.05).

Table 1.
Statistical Description Analysis

Descriptive Statistics					
	N	Min	Max	Mean	Std. Dev
Pre	50	50	70	61.50	5.825
Post	50	70	85	76.20	5.107
Valid N (listwise)	50				

With 50 observations, an average value (mean) of 0.0000000 and a standard deviation of 3.39186420. Given a Kolmogorov-Smirnov z value of 1.980, the absolute value of D is 0.280. Much over the alpha = 0.05 value, or 1.980, is the probability value obtained from this z value. Consequently, we can conclude that the null hypothesis—that the data are regularly distributed—cannot be rejected. The sig value is derived from the above table. (two-tailed) of 0.000 <0.05, after which Ha is approved, and Ho is refused. Therefore, it can be said that there is an influence on the average science literacy from the pre-test to the post-test, indicating that STEAM can enhance PAUD instructors' competency by influencing science literacy. Based on the paired differences, the mean value is -14.700. This figure illustrates the -14.700 difference in average science literacy between the pre-test and average science literacy, which is 61.50 - 76.20—varying between -15.670 and -13.730 (95% Confidence Interval of the Lower and Upper Difference).

Table 2.
Statistical Description Analysis Table. Normality Test with Shapiro-Wilks

Shapiro-Wilk			
	Statistic	df	Sig.
Science literacy	0.966	50	0.507
Teacher competence	0.964	50	0.471

Additionally, the average science literacy score before the exam was lower than the average after the test, as indicated by the negative t-count value of -30.463. This situation allows for a negative t-count value to be positive. Therefore, 30.463 is the t-count value. In cases where a significant level of 5% or 0.05 is used, the t-table has a value of 1.67591. Consequently, it can be said that Ha is accepted while Ho is denied because t-count 30.463 > t-table 1.67591. It is determined that there is an average difference between the science literacy scores of the pre-and post-tests, indicating that utilizing STEAM can enhance science literacy and increase PAUD instructors' competency.

Table 3.
One Sample Kolmogorov-Smirnov Test

One-Sample Kolmogorov-Smirnov Test		
		Unstandardized Residual
N		50
Normal Parameters [a, b]	Mean	.0000000
	Std. Deviation	3.39186420
Most Extreme Differences	Absolute	.280
	Positive	.280
	Negative	-.252
Kolmogorov-Smirnov Z		1.980
Asymp. Sig. (2-tailed)		.001

a. Test distribution is normal.
b. Calculated from data

The findings that emerged from the participants' responses revealed an overwhelmingly positive perception of STEAM-based scientific literacy among early childhood educators. Teachers strongly believe that integrating STEAM enhances their professional and pedagogical competencies, with many agreeing that such training improves their ability to create engaging, student-centered learning environments. Many respondents also recognized the approach's role in fostering creativity, innovation, and the mastery of essential competencies. Findings showed that the teachers expressed their confidence in utilizing simple media to support STEAM-based learning and acknowledged its effectiveness in improving the overall quality of early childhood science education. Most participants also regarded STEAM as an effective way to foster creativity and innovation in their teaching methods and students' learning experiences. Additionally, teachers expressed confidence in using simple and accessible media to implement STEAM-based learning, making it a practical and adaptable approach for early childhood education.

Table 5.
Questionnaire Result

Items	SA	A	N	D	SD
1. STEAM-based scientific literacy training has an impact on increasing the competence of ECSE teachers.	45	5	0	0	0
2. Scientific literacy can increase the creativity of ECSE teachers.	36	10	4	0	0
3. Scientific literacy can improve pedagogic competencies related to ECSE teacher development.	45	5	0	0	0
4. Teachers can create learning conditions while playing through STEAM-based scientific literacy.	50	0	0	0	0
5. STEAM-based science learning in early childhood can utilize simple media.	50	0	0	0	0
6. Through the STEAM approach, ECSE teachers can improve the 6 Cs of students.	50	0	0	0	0
7. STEAM-based science learning can increase the professional competence of ECSE teachers.	50	0	0	0	0
8. The quality of ECSE science learning can be improved through the STEAM approach.	35	15	0	0	0
9. Through the STEAM approach, ECSE teachers can create student-centered learning.	50	0	0	0	0
10. The introduction of STEAM-based scientific literacy increases the literacy understanding of ECSE teachers.	50	0	0	0	0
11. Scientific literacy is very suitable for ECSE students.	48	2	0	0	0
12. ECSE teachers in the Bireuen district can form a community to implement STEAM-based scientific literacy.	45	5	0	0	0
13. STEAM-based science learning can create innovative ECSE teachers.	45	5	0	0	0
14. Through STEAM-based learning, ECSE teachers can master the essential competencies of the taught themes.	35	10	5	0	0
15. ECSE teachers can apply STEAM.	36	10	4	0	0

More importantly, there was a consensus that STEAM enhances teachers' understanding of literacy, reinforcing its value as a foundational framework for teaching in early childhood settings. Beyond personal competence, teachers also emphasized the broader educational benefits of STEAM-based scientific literacy. Most participants agreed that this approach fosters the critical 21st-century skills of their students, particularly the 6Cs (i.e., communication, collaboration, critical thinking, creativity, citizenship, and character). They also highlighted its suitability for early childhood education, suggesting it effectively nurtures young learners' curiosity and engagement. In addition, the participants expressed their confidence in applying STEAM principles in their teaching practices and recognized the potential for forming a professional community to support its implementation. These findings underscore the transformative impact of STEAM in early childhood science education and its value as a tool for both teacher development and student learning.

4. Discussion and Conclusion

Based on the enthusiastic responses from early childhood special education (ECSE) teachers, it is evident that STEAM-based scientific literacy is a beneficial tool and a transformative approach in their professional practice (Butabayeva et al., 2024; Deák & Kumar, 2024). Integrating science, technology, engineering, arts, and mathematics (STEAM) within early childhood education appears to foster a more dynamic and engaging learning environment (Wahyuni, 2024). This multidimensional approach equips educators with the necessary skills to nurture critical thinking, creativity, and problem-solving abilities in young learners. Moreover, the positive influence of STEAM on students' science learning cannot be overstated. By incorporating these diverse disciplines into their teaching strategies, ECSE teachers can present scientific concepts in a more holistic and accessible manner (La Croix et al., 2023; Wan et al., 2021). This method caters to students' varied learning styles and promotes an early appreciation for the interconnectedness of different fields of knowledge. As the world increasingly values interdisciplinary competencies, the role of STEAM in education becomes even more crucial. It prepares students to navigate and thrive in a complex, rapidly changing world by giving them the tools to think creatively and critically. For ECSE students, who may face unique learning challenges, this approach can be particularly empowering, helping them to build confidence in their abilities and foster a lifelong interest in learning (Souto-Manning, 2013). In conclusion, supporting STEAM-based scientific literacy among ECSE teachers highlights a progressive shift in educational paradigms. It underscores the importance of equipping educators with innovative strategies that enhance their teaching capabilities and significantly improve their students' learning outcomes. This approach, with its emphasis on creativity, competence, and pedagogical advancement, is poised to play a pivotal role in the future of early childhood education.

The statistical analysis supports the hypothesis that STEAM-based scientific literacy training significantly improves the competency of early childhood special education (ECSE) teachers. Given that 0.05 is the standard alpha level, the significance level (p-value) achieved is 0.000, which is less. Hence, the alternative hypothesis (Ha) is accepted, and the null hypothesis (Ho) is rejected. The difference between the pre-test and post-test means is shown in the negative t-value (-30.463). A positive influence of STEAM-based training on scientific literacy may be inferred from the negative t-value in this case. The null hypothesis is rejected since the t-value is considerably more significant than the critical t-table (1.67591) at a 5% significance level. Based on the statistical analysis, it can be concluded that there is a noteworthy distinction in the mean scores between the scientific literacy pre- and post-tests. This suggests that incorporating STEAM into scientific literacy training enhances the proficiency of early

childhood special education (ECSE) teachers. The results indicate that incorporating STEAM concepts into teacher preparation programs may help improve teachers' abilities in early childhood education.

Ethical Issues

The authors confirm that ethical approval was obtained from Universitas Almuslim (Approval Date: 08/09/2024). Each participant was asked to sign a consent form according to ethical research rules in the author's country.

Conflict of Interest

The authors declared no conflict of interest.

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